

## SUBSTRATE AND MOISTURE PREFERENCES IN COMMON TOAD BUG, *GELASTOCORIS OCULATUS* (HEMIPTERA: GELASTOCORIDAE)<sup>1</sup>

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**ABSTRACT:** The diel preferences of 300 adult *Gelastocoris oculatus* were tested by simultaneously presenting them with four dry substrates of soil, sand, rocks, and vegetated soil. The subjects exhibited a strong daytime preference (147 of 300) for the rock substrate and a moderate daytime preference (89 of 300) for the vegetated substrate. In the nighttime tests, the toad bugs were more evenly distributed, but exhibited some preference for sand, rocks, and vegetated soil. Daytime and nighttime experiments with choices of four damp substrates had similar results, with the greatest number of subjects aggregated around and under rocks, whereas in experiments with wet substrates, no definite substrate preference was discernible in either the daytime or nighttime tests. Results of these and additional experiments as well as field observations show that adults of *G. oculatus* prefer damp substrates to water saturated, or wet, substrates, that they avoid direct sunlight when in a state of partial desiccation in dry habitats, and that they can and do suck water directly from the substrate.

**DESCRIPTORS:** Hemiptera: Gelastocoridae; *Gelastocoris oculatus*; substrate and moisture preferences; diel rhythm; behavioral temperature regulation.

Species of the genus *Gelastocoris* (commonly called toad bugs) are known only from the Western Hemisphere. *Gelastocoris oculatus* (Fabricius), the most common Nearctic species, is distributed, according to Todd (1955), from southern Canada into Mexico. Hungerford (1922) reported it to be predaceous in the nymphal and adult stages. Uhler (1884) stated that this species could be found on the low banks of brooks and streams where grouse locusts occur. Hungerford (1920, 1922), Blatchley (1926), Smith *et al* (1943), Ellis (1952), Todd (1955), Usinger (1956), and Wilson (1958) all indicate that the species occurs on mud and sand banks of streams, ponds, and swamps. Hungerford (1920) and Mackey (1972) noted that this species exists as spatially discrete colonies. Hungerford (1920, p. 49) stated, "A colony may be found in one spot along a given stretch of the stream and nowhere else." This isolation pattern of distribution may be related to the rarity or absence of flight in the species as reported by Todd (1955) and Parsons (1959).

<sup>1</sup>Accepted for publication: May 10, 1976.

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Torre-Bueno (1912) inferred from the collection of several second-instar nymphs in September on Long Island that *G. oculatus* could overwinter as a nymphal instar, but Hungerford (1920, p. 49) stated that, "Our Kansas forms winter as adults, burying themselves in the sand." Blatchley (1926) found both adults and larger nymphs hibernating in cavities in mud shores of streams and lakes in Indiana and in Missouri Froeschner (1962) found this species overwintering as adults under stream-drift debris. Overwintering adults were reported in southern Canada by Brooks and Kelton (1967).

According to Uhler (1884), there are two distinct generations of *G. oculatus* in the eastern United States, with the second developing in August. Recently, however, Mackey (1972) interpreted data on egg production, presence of sperm in females, and seasonal occurrence of instars as indicating that eastern Tennessee populations are univoltine and overwinter as adults. Polhemus (personal communication) collected adults in January and March of 1975 on the South Platte River at Waterton, Colorado. During the present study, the senior author collected one fifth-instar nymph and 17 adults in early October.

The objective of the present study was to determine the specific substrates where this species is most likely to be found under different moisture conditions in daylight and darkness. No previous research has been performed on this problem, although Hungerford (1922) performed a simple two-substrate preference experiment with *G. oculatus*, which was mainly related to the great color variation (apparently substrate-correlated) observed in *G. oculatus* by Hungerford and earlier workers. In addition, Hungerford (1920, 1922) established that, under certain conditions, *G. oculatus* will burrow into sand and mud.

### Materials and Methods

The project was conducted in the spring of 1972 and the summers of 1973-74. The materials consisted of a fiber-board test chamber 50.7 cm long x 36 cm wide x 35.5 cm deep on legs 2.5 cm tall. A cardboard divider, which when placed in the chamber, divided it into four equal compartments each containing an individual substrate box. Each substrate box measured 24.3 x 17.8 x 3.8 cm and was lined with a clear plastic sheet. Four of these substrate boxes completely covered the bottom of the test chamber. A strip of smooth aluminum tape was placed horizontally around the inside of the test chamber 19.1 cm from the bottom to prevent escape of the toad bugs. The substrates tested were loam soil, sand, rocks, and vegetated soil. The rocks were underlain with sand and the vegetation box contained a mixed substrate of loam soil, stream sand, and small stones with a growth of scattered grasses and sedges. All substrates were obtained from the general habitat of the toad

bugs (Bull Run Creek, Peffer Memorial Park, Oxford, Ohio). Voucher specimens of the gelastocorids tested are in the Miami University Insect Collection.

For the nighttime experiments, a fiber-board lid and black plastic cover were placed over the test chamber to shield it from artificial light. V-shaped cardboard guides glued on the middle of each inside wall of the test chamber facilitated rapid insertion of the compartment divider. The daylight condition was augmented by placing a 15-watt white fluorescent lamp (40.6 cm long) centrally and 61 cm above the substrates in the test chamber. The test chamber was maintained at 22°C.

Between experiments, the toad bugs were retained in 19-liter aquaria (supplied with sand, vegetation, and water from their habitat) and fed miscellaneous small live insects collected by sweeping. No prey or food was allowed in the test chamber.

In conducting each experimental replication, 100 adult toad bugs were passed through a paper funnel into the middle of the test chamber to the junction point of the four substrate boxes. Five hours of daylight and 10 hours of darkness were allowed for dispersion of the 100 insects in the substrate units. A longer dark period was deemed necessary because toad bugs move more slowly and less frequently in darkness (Deonier, unpublished data). At the end of each test period, the divider was rapidly, but carefully, inserted. Because toad bugs usually lower their bodies and remain still if disturbed, but not touched, and because no toad bugs were seen to jump about during this insertion, the authors have concluded that the distribution of the subjects was little affected by the slight disturbance of divider insertion.

The first series of experiments with soil, sand, rocks, and vegetated soil was performed in the following sequence: dry (day), dry (night), damp (day), damp (night), wet (day), and wet (night). For a control series, sand was used in each substrate box. Using the two substrates (rocks and vegetated soil) most preferred in this series, a second series of experiments was done with dry/damp and damp/wet as the paired contrasting moisture choices under day and night conditions. The controls consisted of four boxes of dry rock substrate and four boxes of damp vegetated soil. Each experiment of the two series had three replicates. All of the replicates of each experiment were combined for the final analysis since there was no significant statistical difference between the replicates of any one experiment.

In both experimental series, the terms dry, damp, and wet were defined as follows:

- dry – dry to the touch, little or no moisture present in the substrate
- damp – moist to the touch, but no standing water
- wet – moist to the touch and with patches of standing water

A chi-square ( $X^2$ ) analysis of the five control series showed that none of them deviated significantly ( $p \geq .1$ ) from an expected random (even) distribution. Each of the series of preference tests were, therefore, compared to a random distribution by means of a chi-square analysis.

### Results

In the first experiment involving dry substrates in the daytime (Fig. 1), the distribution of the toad bugs was significantly different from the expected random distribution ( $X^2=121.15$ ,  $p \leq .001$ ). The subjects exhibited a strong preference for the rock substrate and a moderate preference for the vegetated substrate. It was noted that the toad bugs in the soil and sand boxes had dug into the substrate. In the nighttime test (Fig. 1), the insects were more evenly distributed, but their distribution was still significantly different from the expected ( $X^2=12.29$ ,  $p \leq .01$ ). The sand, rocks, and vegetated substrates were preferred equally, but the soil substrate seemed to be somewhat less preferred.

The results of the daytime and nighttime experiments with damp substrates (Fig. 2) show similarities to those with dry substrates. In the day, the distribution of toad bugs was significantly different from the expected ( $X^2=62.35$ ,  $p \leq .001$ ) with the insects exhibiting a distinct preference for the rock and vegetated substrates, which in nature would offer some shelter from direct sunlight. Again, the greatest number aggregated around and under rocks. Most of those in the soil substrate were found under clumps of mud. The nighttime experiment showed a somewhat more equal dispersion, but this distribution also deviated significantly from the expected ( $X^2=18.59$ ,

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Fig. 1. Distributions of 300 toad bugs on four dry substrates during day and night tests.

Fig. 2. Distributions of 300 toad bugs on four damp substrates during day and night tests.

Fig. 3. Distributions of 300 toad bugs on four wet substrates during day and night tests.

Fig. 4. Distributions of 300 toad bugs on dry and damp substrates during day and night tests.

Fig. 5. Distributions of 300 toad bugs on damp and wet substrates during day and night tests.

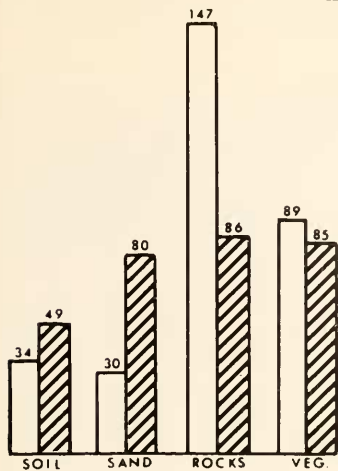


FIG 1

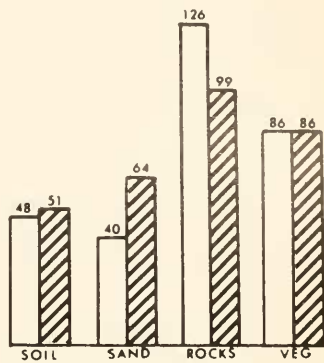


FIG 2

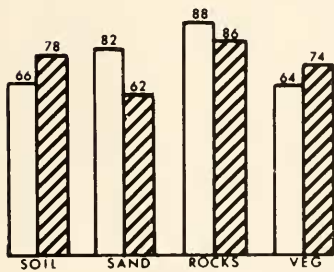


FIG 3

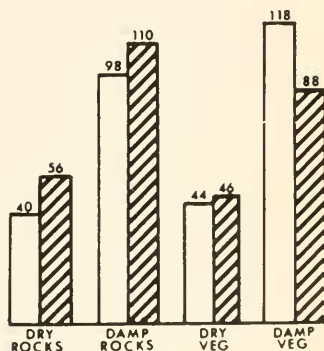


FIG 4

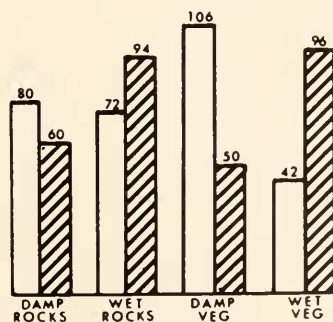


FIG 5



$p \leq .01$ ). In this test, there was a slight preference for the rock and vegetated substrates.

In the experiments with wet substrates (Fig. 3), no definite preference was observed in either the daytime ( $X^2=5.60$ ,  $p \geq .1$ ) or nighttime ( $X^2=4.00$ ,  $p \geq .1$ ) tests. Also, the bugs did not dig into the sand and soil substrates nor did they exhibit any strong tendency to hide under rocks, clumps of soil, or in vegetation.

When comparing the distributions in two dry and two damp substrates (Fig. 4), the subjects showed a definite preference for the damp substrates under both day ( $X^2=60.85$ ,  $p \leq .001$ ) and night ( $X^2 = 34.61$ ,  $p \leq .001$ ) conditions. Those insects found in the dry substrates were hidden under rocks, in the soil, or under dry vegetation. The comparisons between damp and wet substrates (Fig. 5) showed a distinct preference for the damp vegetation during the day ( $X^2=27.79$ ,  $p \leq .001$ ) and a moderate preference for the wet rocks and wet vegetation during the night ( $X^2=22.03$ ,  $p \leq .001$ ).

In another experiment, subsequent to the substrate-preference tests, toad bugs were placed on a dry white-sand surface bearing one central cluster of small stones and irradiated directly with a 150-watt incandescent lamp. The dry sand ranged from 40-43°C and was saturated with water after 2.5 hours. In ten replications, each with a new group of three bugs, 18 sought shelter under the stones and 12 burrowed completely or partially into the sand during the first 0.5-1 hour, but only 4 remained continuously sheltered after saturation. Immediately upon saturation, all of the bugs probed their beaks into the wet sand and held them there for about 5 minutes. In the field, five toad bugs, when restrained in dry rocky habitat, took shelter from direct, intense sunlight after 0.5 to 1.25 hours. The substrate surface temperature was approximately 40°C. All probed into wet sand after their release.

## Discussion

The results of the present study indicate that adults of *Gelastocoris oculatus* prefer damp substrates to water-saturated, or wet, substrates and that they avoid direct sunlight in dry habitats when in certain physiological states. That desiccation and supra-optimal body temperature are two of these states is indicated by the results, especially those from the additional field and laboratory tests.

In support of these interpretations, Bursell (1974) and Edney (1971) showed that exposure of insects to direct sunlight causes their temperature to rise measurably above the ambient air temperature. Insect size and shape as well as air current velocities were considered to be the significant factors affecting temperature excess of the exposed insects. *Gelastocoris oculatus* would appear to have a size and shape conducive to overheating. However, as Bursell (1974) noted, the heterogeneity of most natural insect habitats is such

that indirect temperature regulation can be effected by appropriate shelter-seeking or avoidance behavior. Cloudsley-Thompson (1970, 1975) cited numerous examples which support his generalization that, "temperature regulation in arthropods is very largely behavioral." *Stizopina* tenebrionid beetles of the Namib Desert are arenicolous, but if stones are available they hide under them during the day instead of burrowing (Cloudsley-Thompson, 1975). Other examples cited by this author include three species of desert tenebrionids which respond to near-lethal temperatures by burrowing into sand and *Blaps sulcata*, a xerobiontic tenebrionid, which, in Israel, aggregates during the day under thick, flat stones.

In cases taxonomically closer to *Gelastocoris*, Heath (1967) reported that adult *Magisicada casini* seek shade when their body temperature exceeds 34°C, and Lindskog (1968) presented evidence that direct radiation from the sun affects body temperature and transpiration rate in *Saldula saltatoria* Linnaeus (Hemiptera: Saldidae). Furthermore, Lindskog found that, in the field, shore bugs of this species compensated for water loss by ingesting free water. He observed that adult *S. saltatoria* frequently bask in the sun and that afterwards they almost always drink at first contact with a moist substrate. Equally relevant to our results is his statement (1968, p. 466) that the nymphs of this species "succeed under certain conditions in completing their development on quite dry soil, provided there is sufficient shelter."

In conclusion, it appears that the burrowing behavior of *Gelastocoris oculatus* together with its facultative negative phototaxis and positive hygrotaxis (as revealed by the present study) equip this apparently flightless insect for survival on substrates of greatly varying moisture content and texture, which it undoubtedly traverses in the normal course of searching for prey and mates.

#### ACKNOWLEDGEMENTS

We thank Professor M.W. Boesel and Dr. J.T. Polhemus for their critical reviews of the manuscript.

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